

The University of Chicago

THE MAGNETIC SUSCEPTIBILITY OF
SODIUM IN LIQUID AMMONIA
AND ITS RELATION TO THE
FERMI-DIRAC STATISTICS

A DISSERTATION SUBMITTED TO THE FACULTY
OF THE DIVISION OF THE PHYSICAL SCIENCES
IN CANDIDACY FOR THE DEGREE OF DOCTOR
OF PHILOSOPHY

DEPARTMENT OF CHEMISTRY

1939

By

RICHARD PUTNAM METCALF

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INTRODUCTION

The magnetic susceptibility of a metal, like its specific heat, is anomalous in that the free electrons do not make the contribution to be expected from the "classical" electron gas theory of Drude and Lorentz. Each free electron has a magnetic moment of $\sqrt{3}$ Bohr magnetons, due to its spin. If the electrons behaved as a classical ideal gas, such a moment should lead to a molar susceptibility of $0.372/T$, where T is the absolute temperature.¹ The contribution actually made by the free electrons can be estimated by subtracting the susceptibility of the positive ions from the measured value for the metal. Such a calculation reveals a susceptibility of only about 10^{-5} per mole attributable to free electrons, and this is nearly independent of temperature.²

The development of the quantum mechanics has led to a theory of the metallic state which gives a satisfactory, though often qualitative, interpretation of most of the characteristic properties of metals.³ The feeble, temperature-independent paramagnetism of metals was first explained by Pauli, who showed that, since the electrons obey the Fermi-Dirac statistics, nearly all of them are paired with others of opposite spin and therefore do not respond to an external field.⁴ The characteristic variable of Pauli's theory is the quantity T/T_0 , where T_0 is the degeneracy temperature, defined by

$$T_0 = \frac{h^2}{8mk} \left(\frac{3N}{\pi} \right)^{2/3},$$

where h is Planck's constant, k Boltzmann's constant, m the mass of the electron, and N the number of electrons per cc. When

¹E. C. Stoner, "Magnetism and Matter," Methuen and Co., London, 1934, chap. x.

²Ibid., chap. xiv.

³Several excellent monographs on this subject are available; one, e.g., by N. F. Mott and H. Jones, "The Theory of the Properties of Metals and Alloys," Oxford University Press, Oxford, 1936.

⁴W. Pauli Jr., Z. Physik, 41, 81 (1927).

$T \ll T_0$, the paramagnetism is small and nearly independent of temperature; when $T \gg T_0$, the classical behavior would be approached. For ordinary metals, T_0 is of the order of 10,000° K.

Evidently T/T_0 may be increased, not only by increasing T , but also by decreasing the concentration of free electrons. This would presumably require dissolving a metal in a non-metal to form a solution which possessed metallic properties.

The solutions of the alkali and alkaline earth metals in liquid ammonia appear to satisfy these conditions.⁵ The concentrated solutions, which may contain as much as ten or twenty mole per cent of metal, are metallic in appearance, have a high electrical conductivity,⁶ and show a photoelectric effect with visible light.⁷ In more dilute solutions, which have an intense blue color, the variation of the conductivity with concentration resembles that for a strong electrolyte.⁸ Kraus has shown that when the solutions are electrolyzed the only material effect is a transference of the metal toward the cathode. He has shown further that the solutions contain positive metal ions identical with those present in salt solutions, and negative carriers which can only be electrons, either free or in association with ammonia.⁹ Studies of the electromotive force of concentration cells showed that in dilute solutions the mobility of the negative carrier is about seven times that of the sodium ion. As the concentration is increased, the mobility of the electrons increases rapidly, and in very concentrated solutions the conductivity is entirely metallic.¹⁰

⁵For reviews of the extensive literature on these solutions, see W. C. Johnson and W. C. Fernelius, J. Chem. Education, **6**, 20 (1929); C. A. Kraus, J. Franklin Inst., **212**, 537 (1931).

⁶H. P. Gady, J. Phys. Chem., **1**, 707 (1897).

⁷Kraus, J. Am. Chem. Soc., **43**, 749 (1921); G. A. Crapple, "A Study in the Photoelectric Effect of Solutions of Sodium in Liquid Ammonia," Master's thesis, Dept. of Chemistry, University of Chicago, 1933; G. M. Schmeing, "A Study of the Spectral Photoelectric Response of Solutions of Sodium in Liquid Ammonia," Ph.D. dissertation, Dept. of Chemistry, University of Chicago, 1939.

⁸Kraus, J. Am. Chem. Soc., **43**, 749 (1921); G. E. Gibson and T. E. Phipps, ibid., **48**, 312 (1926).

⁹Kraus, ibid., **30**, 1323 (1908).

¹⁰Kraus, ibid., **36**, 864 (1914).

It may be concluded that the solutions of metals in liquid ammonia are systems having metallic properties and in which the concentration of the metal can be varied continuously over an extremely wide range.

At the boiling point of liquid ammonia, -33°C. or 240°K. , the molal magnetic susceptibility of a classical free electron gas would be $0.372/240 = 1550 \times 10^{-6}$, whereas we have seen that for the degenerate electron gas in a metal, the susceptibility is about 10×10^{-6} . It would therefore be expected that on sufficient dilution of a solution of, say, sodium in liquid ammonia, the molal susceptibility would increase from about 10×10^{-6} in a concentrated solution to 1550×10^{-6} at high dilutions.¹¹ Further, this increase should occur in the neighborhood of the concentration for which $T/T_0 = 1$. Now $T_0 = 240$ when $N = 1.369 \times 10^{19}$ electrons per cc. On the assumption that each sodium atom contributes one free electron, this corresponds to a concentration of 5.64×10^{-4} moles of sodium per mole of ammonia.

The magnetic susceptibilities of a number of solutions of sodium in liquid ammonia were measured at 230°K. by Freed and Thode, who found that the molal susceptibility of the sodium increased from 9×10^{-6} in a fairly concentrated solution to about 1100×10^{-6} in dilute solutions. The susceptibility increased most rapidly in the neighborhood of a concentration of 10^{-4} moles of sodium per mole of ammonia.¹² This result was confirmed by the more extensive investigation of Huster.¹³

The limiting value of the molal susceptibility as the concentration approaches zero is of especial interest since Landau has shown that free electrons have a diamagnetism, due to their translational motion, which is numerically equal to one-third of the spin paramagnetism.¹⁴ Therefore, if the electrons are free even in the dilute solutions, the limiting value of the suscepti-

¹¹The molal susceptibility of sodium ion is only about -5×10^{-6} Stoner, "Magnetism and Matter," p. 271.

¹²S. Freed and H. G. Thode, Nature, **134**, 774 (1934); Thode, "A Study of the Metallic State and the Magnetic Susceptibilities of Sodium in Liquid Ammonia," Ph.D. dissertation, Dept. of Chemistry, University of Chicago, 1934.

¹³E. Huster, Ann. Physik (5), **33**, 477 (1938).

¹⁴L. Landau, Z. Physik, **64**, 629 (1930).

bility should be $0.248/T$, whereas if they are bound to a heavier center, such as a molecule of ammonia, the limiting value should be $0.372/T$. The large increase in molal susceptibility occurs at such low concentrations that, in spite of the large value of the molal susceptibility, the actual susceptibility of the solution differs only slightly from that of pure ammonia. The determination of the limiting susceptibility therefore requires a rather accurate measurement of this small difference. Neither Thode nor Huster was able to settle this point conclusively.

Some information on this question may perhaps be derived from the temperature dependence of the susceptibility. As stated above, a classical free electron gas should obey Curie's law; that is, the susceptibility should be inversely proportional to the absolute temperature. The temperature coefficient should therefore be negative, and at -33° it should be about $1/240$ per degree. On the other hand, the temperature coefficient for a degenerate electron gas should be quite small. Ideally, the temperature coefficient at constant volume should be negative, but the volume change due to thermal expansion is often sufficient to produce a positive temperature coefficient at constant pressure.¹⁵

At a mole ratio of 4×10^{-3} , Thode found a large positive temperature coefficient. At 5×10^{-5} the temperature coefficient agreed with Curie's law, being about -5% per degree, but the effect was hardly greater than the error of measurement. Huster found positive temperature coefficients for all his solutions, whose mole ratios ranged down to 2×10^{-5} . When the temperature coefficient is measured by lowering the temperature, the effect of this on the dilution necessary to make $T/T_0 = 1$ should be considered. Thus at the freezing point of ammonia, -78° C., $T/T_0 = 1$ at a mole ratio of 3.8×10^{-4} . Further, Huster has found that at intermediate concentrations the temperature coefficient is much too large to account for without additional hypotheses. The same effects may possibly complicate the situation at lower concentrations.

The present investigation has been primarily devoted to building an apparatus which would make possible the determination of the limiting value of the susceptibility at low concentrations.

¹⁵Stoner, Proc. Roy. Soc. (London), 152A, 672 (1935).

This end has not yet been attained. Several measurements have been made in the hope of improving the data in the range where the susceptibility increases most rapidly.

EXPERIMENTAL

The susceptibility determinations were made by the Gouy method, whereby a cylinder of the material is suspended from a balance with one end in the uniform field between the pole pieces of a magnet. The vertical force on the cylinder is measured by weighing with the field both off and on. The susceptibility per unit volume, K , is then

$$K = \frac{2F}{A(H_1^2 - H_2^2)},$$

where F is the force in dynes, A the cross-sectional area of the cylinder, H_1 the magnetic intensity at the center of the magnet, and H_2 the field at the other end of the cylinder (usually negligible). The solution was contained in the tube G , Figure 2, which was divided by a transverse partition into two compartments. One of these was filled with the solution and the other with pure solvent. The small difference between the susceptibilities of solution and solvent was thus measured directly.¹⁶

Preparation of the Solutions

The solutions were prepared in an all-glass vacuum system, using the method adapted by Thode from procedures developed by Kraus.¹⁷ The apparatus is shown in Figure 1. Sodium was introduced into A through a tube which was then sealed off at B . Anhydrous ammonia was condensed on the sodium until the level of the solution was above the ends of the siphon tubes. The solution could be stirred by the sealed glass tube C , containing a piece of iron, which could be moved by means of a solenoid surrounding the cooling bath. It was frequently convenient to put an excess of sodium into A . When this was done, the concentration was adjusted to the desired value by siphoning part of the solution into D and distilling the ammonia back into A . This process could be re-

¹⁶S. Freed and C. Kasper, Phys. Rev., **36**, 1002 (1930).

¹⁷Thode, Ph.D. dissertation.

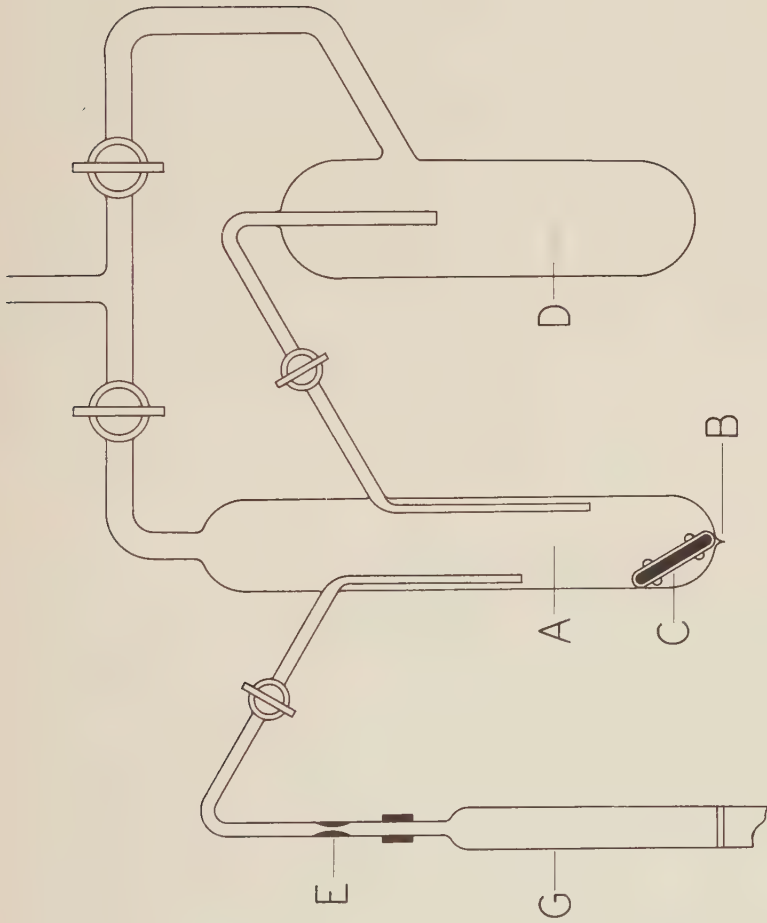


FIG. 1

peated if necessary. When the desired concentration was attained, part of the solution was siphoned into G, which was then sealed off at E.

After the top end of G had been filled with solution, the lower end was sealed to the line, filled with liquid ammonia, and sealed off.

Liquid ammonia in open dewar flasks was used for all cooling baths. The temperature of such a bath can be reduced to -50° or lower by blowing a stream of air on the surface. A heater made of bare resistance wire was used to warm the baths up to the boiling point, -33° , when necessary.

Introduction of sodium.--The method of forcing molten sodium through a capillary tube by means of gas pressure¹⁸ has been found unsatisfactory for small quantities of sodium because of the uncertainty as to the fraction of the metal which is actually transferred. An attempt was made to modify this method to obtain more positive control of the quantity of sodium transferred, but the resulting apparatus was very cumbersome and difficult to operate. In one experiment the sodium was introduced by distillation¹⁹ at a temperature of about 250° . This method seemed very promising, though it would be tedious for large quantities of sodium.

Determination of the concentration.--The amount of ammonia involved in any operation could be determined accurately by means of three graduated measuring cells of the type described by Kraus.²⁰ It was thus possible to calculate the concentration of the final solution in A, used to fill G, either from the amount of sodium siphoned into D or from the amount remaining in A. These quantities were determined by washing the tubes out with water and titrating the resulting sodium hydroxide solutions with 0.01 N hydrochloric acid, after boiling to remove ammonia.

The calculation based on the sodium in A is of course more direct, but would give too high a concentration if any of the sodium were oxidized or formed other compounds insoluble in

¹⁸C. A. Kraus and W. W. Lucasse, J. Am. Chem. Soc., **43**, 2529 (1921).

¹⁹Gibson and Phipps, J. Am. Chem. Soc., **48**, 312 (1926); Huster, Ann. Physik (5), **33**, 477 (1938).

²⁰Kraus, J. Am. Chem. Soc., **43**, 749 (1921).

ammonia but soluble in water. This happened at least once. Both calculations require that the solution in G have the same composition as the solution in A, which is not always true. In two cases a considerable amount of ammonia distilled into G, and a correction had to be estimated. It would be preferable to analyze the solution in G directly. This would not be too easy, since in the most dilute solutions G will contain only a few hundredths of a milligram of sodium. The present unsatisfactory situation is shown in Table 1. It could unquestionably be improved with practice, however, even using the same technique.

TABLE 1

Solution	Mole Ratio Based on Sodium in		Mole Ratio Adopted
	A	D	
1	2.7×10^{-4}		2.4×10^{-4}
2	4.1×10^{-4}	2.3×10^{-4}	2.3×10^{-4}
3	8.4×10^{-5}	7.7×10^{-5}	8.0×10^{-5}
4	1.17×10^{-4}	1.10×10^{-4}	9.1×10^{-5}

Susceptibility Measurements

The apparatus used for the susceptibility measurements, Figure 2, was similar to that described by Freed²¹ but included several new features. The inner jacket H was made of glass instead of metal. This made possible the use of liquid ammonia for the cooling bath. Also the tube G could be examined at any time through an unsilvered strip running the length of the dewar flask F; this made the alinement of the apparatus a matter of a few minutes rather than days. The hydrogen stream was introduced through J at the top of H instead of at the bottom. The other new feature was that the dewar flask F had a circular cross-section throughout. The clearance between H and the narrow lower end of the dewar was only about 0.03 in. The tubes T, T contained single-junction copper-constantan thermocouples. The top of the dewar was closed by a stopper (not shown) which supported H and also carried connections to a manometer and to a vacuum pump for

²¹Freed, J. Am. Chem. Soc., 52, 2702 (1930).

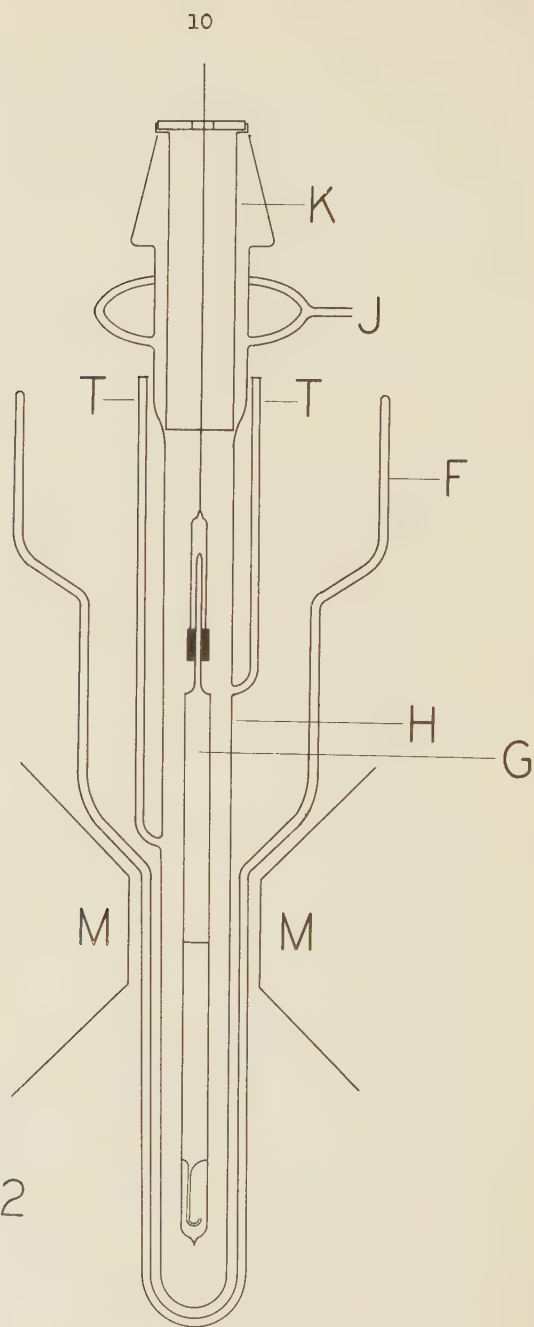


FIG. 2

reducing the temperature of the bath. M, M are the poles of the magnet.

The tube G was made of Jena KPG precision tubing, which seals directly to pyrex. The inside diameter was 5.00 mm.; the outside diameter was about 8 mm. and was less uniform. The cylindrical portion of the tube was 25 cm. long. A pyrex partition was sealed across the middle. The trap at the lower end prevented the bubble which was left after sealing off from rising to the partition. At the top end, sealing to the vacuum line, and so forth, was done above the point at which the suspension was attached, so that the position of the tube in the field could be reproduced easily. The suspension was made of light gold-plated chain.

After the tube G had been filled, it was always dipped in a bath of fresh liquid ammonia, and then transferred quickly to H. H was then closed with a ground glass cap and evacuated through J for several hours with a hyvac pump to remove ammonia and moisture. When this procedure was followed, there was no trouble from electrostatic charges on the glass.

When the measurements were to be made, hydrogen was admitted through J until the pressure reached that of the atmosphere. Then the cap was removed from H and the suspension was connected to the balance. It looks as though it would not be necessary for the flowing hydrogen to come in contact with any cold parts of the apparatus, but it was found that G gained weight unless the hydrogen was dried rather carefully. The flow of the hydrogen was diffused by the perforated metal cylinder K which was covered by a metal disk through which the suspension passed. Although the hole in the disk is only 0.09 in. in diameter, a flow of almost 100 cc. per minute was necessary to prevent the entrance of air. This exerted an upward drag on the suspension of about 0.1 mg., but the flow was so constant that no variations in weight could be traced to this source. The flow was controlled by a capillary valve as described by Freed.²²

Balance and method of weighing.--The weighings were made with a Kuhlmann microbalance. This instrument was the regular model 19C balance with a few modifications such as the elimination of ferromagnetic material from the beam and the lengthening of the

²² Ibid.

telescope. The rider weighed 0.5 mg., but additional weights totalling 10 mg. could be manipulated from outside the balance case. The sensitivity of the 19C balance is such that 0.0001 mg. can be estimated easily, but the reproducibility of the rest point on this instrument is seldom better than 0.003 mg.

Since microbalances are known to be very easily deranged by temperature fluctuations, elaborate precautions were taken. The balance was surrounded by a transite box lined with sheet aluminum, which in turn was inside a much larger box of celotex. The controls for the arrestment and riders were brought out to the side through the transite box. The arrestment control was further brought out to the front through the celotex box by using a 20:1 worm gear, but it was necessary to reach inside the celotex box to operate the rider controls. The arrangement was such that the balance telescope extended through the front of the celotex box. Thermostatic control was provided for the celotex box, but its use was discontinued since it did not improve the behavior of the balance.

Marked improvement in the reproducibility of the rest point was achieved by the use of a special method of arrestment whereby the arrestment contacts are raised just enough to stop the oscillations of the beam, but not so much as to lift the knife edges away from the planes. This requires very delicate manipulation of the arrestment, which one can attain by operating it with the 20:1 worm gear while observing the cross hair in the telescope. This procedure was inspired by the clamping method used by Poynting.²³ Usually there was not much difficulty in weighing to 0.001 mg. by this method. No effort was made to do better. No attempt has been made to use the method when it was necessary to change objects on the balance pans, but it has served admirably for the magnetic work where it was merely necessary to move the rider.

For the magnetic work, the pan arrests and the left pan itself were removed. The suspension for tube G was hung from the left stirrup and passed through the hole in the base plate left by the removal of the pan arrest. The suspension passed through small holes in brass diaphragms both at the base plate of the

²³J. H. Poynting, Proc. Roy. Soc. (London), 28, 2 (1879); P. R. Heyl, Bur. Standards Sci. Papers, 19, No. 482, 307 (1924).

balance and at the floor of the transite box. Between the transite box and the celotex box the suspension was inclosed in a 5/8 in. brass tube. Between the end of this brass tube and the top of tube H, the suspension was surrounded by a piece of celluloid bent into a cylinder. It was necessary to make this cylinder fit loosely so the hydrogen could escape easily.

The hole left by the removal of the right pan arrest was used for a tube connected with a small rubber bulb by means of which a gentle puff of air could be directed against the right pan. This was used to increase or decrease the amplitude of the balance swings.

With the arrangement described, the swings of the balance were practically as steady as when the pans were in place. Disturbing factors were air currents in the room, such as those produced by people walking about; and fluctuations in the room temperature. An increase of 0.1° C. in the room temperature produced an apparent increase of about 0.001 mg. in the weight of the tube. The cause of this effect is unknown. In order to keep a check on it, the room temperature was read frequently on a thermometer graduated in tenths of a degree.

Since the rest point usually drifted more or less rapidly when the tube was suspended, readings were taken every three minutes for some time before and after a weighing and interpolated values were used. Times were recorded to the nearest five seconds. Satisfactory results could be obtained even when the weight was changing rather rapidly.

Magnet.--The electromagnet was of the type described by Carragan.²⁴ It was equipped with pole pieces of Swedish iron tapered to 1 in. in diameter at the ends and separated by a gap of slightly over 1 in. With 15 amp. flowing, a field of about 15,500 gauss was produced. Hysteresis was extremely small. The ammeter readings could be estimated to about 0.02 amp., but the last figure is not very significant because the magnet heated up so rapidly that the current often dropped 0.1 to 0.3 amp. during a weighing. Weighings were made at approximately 3, 6, 9, 12, and 16 amp. The original intention was to find out whether the susceptibility was independent of the field, but actually all the calculations have been based on interpolations to a current of

²⁴G. H. Carragan, Astrophys. J., 63, 145 (1926).

15 amp.

Calibration and blank runs.--When the Gouy method is to be used for relative measurements of susceptibility, as in the present case, three measurements are necessary: one with the material to be measured, one with the standard substance, and a blank run on the container.

For the calibration, the top end only of tube G was filled with pure liquid ammonia. The susceptibility of ammonia has been determined by Huster with an accuracy of one or two per cent,²⁵ which was adequate for the present purpose. The data are given in Table 2. The "tube factor" is the ratio of the susceptibility to the pull. It is evidently a constant over this short range of temperatures.

TABLE 2

	-33°	-45°	-55°
Pull (corrected)	-15.96 mg.	-16.28 mg.	-16.51 mg.
χ (ammonia), $\times 10^6$	- 0.6622	- 0.6747	- 0.6852
Tube factor, $\times 10^6$	0.04150	0.04144	0.04150

For the blank runs, both ends of the tube G were filled with liquid ammonia. Ideally the pull under these conditions should be zero, but deviations from perfect symmetry may be expected to produce a small effect. With the apparatus used, the field at the ends of the cylindrical portion of the tube was about 800 gauss, which means that the term in H_2^2 in the expression for the pull amounts to about 0.04 mg. One would expect the effects of the two ends to cancel approximately, but since the field varies rapidly near the ends of the tube, the pull may be quite sensitive to slight changes in the exact position of the tube relative to the magnet. Also it is possible that the balance between the effects of the two ends may be easily disturbed if there are variable temperature gradients in the cooling bath. Actually, the pulls varied erratically by as much as 0.03 mg. Such irregularities made measurements on really dilute solutions out of the question, and seriously affected the accuracy attainable at higher

²⁵Huster, Ann. Physik (5), **33**, 477 (1938).

concentrations.

Measurements at lower temperatures.--With a reasonably fast pump it was found easy to reduce the temperature of the liquid ammonia bath to the freezing point, -78° . However, at the lower temperatures the bath bumped so violently as to make weighing impossible. Several methods were tried for controlling the bumping, but none of them were entirely satisfactory. The most effective, when it worked, was to bubble nitrogen from a capillary tube. The capillary had to be very narrow to get to the bottom of the dewar, and no way was found to keep it from getting stopped up with ice. Less satisfactory, but more dependable, was a coil of resistance wire at the bottom of the dewar, which could be heated electrically. Platinum was used to reduce corrosion. In this way it was usually possible to weigh at temperatures down to -55° or -60° . At lower temperatures, and sometimes at higher, bumping persisted in spite of the heater.

Another difficulty has been the absence of any dependable regulation of the pressure on the bath. Thus the temperature has been able to change enough to alter the buoyant effect of the hydrogen on the tube. A rough calculation indicates an effect of about 0.004 mg. per degree.

The rate of attainment of thermal equilibrium could be observed by watching the change in the level of the liquid in the narrow part of tube G. It was surprisingly rapid.

Results.--The results are given in Table 3 and are compared with previous results in Figure 3. The difference between the volume susceptibilities of the solution and of ammonia is obtained by multiplying the pull by the tube factor (Table 2). The molal susceptibility, χ , of the sodium is found by dividing this result by the concentration in moles per cc. It was assumed that the density of the solutions was equal to that of pure ammonia,²⁶ which is quite accurately true for such dilute solutions.²⁷

The uncertainties in the concentration of the solutions have been discussed in connection with Table 1. Estimated limits

²⁶C. S. Cragoe and D. R. Harper 3d, Bur. Standards Sci. Papers, 17, No. 420, 287 (1921).

²⁷C. A. Kraus, E. S. Carney, and W. C. Johnson, J. Am. Chem. Soc., 49, 2206 (1927); W. C. Johnson and A. W. Meyer, ibid., 54, 3621 (1932); Huster, Ann. Physik (5), 33, 477 (1938).

of error based on the magnetic results alone are for solutions 1 and 2, 10%; for solution 3, 25%. Solution 4 was probably decomposing; it was obviously more dilute than solution 3 at the time the measurements were made.

The only definite conclusion which can be drawn is that the results of Thode in the neighborhood of a mole ratio of 2.5×10^{-4} are probably too low. It seems improbable that the result of 1320×10^{-6} at a mole ratio of 8×10^{-5} can be much too high, since most of the uncertain factors were weighted in such a way as to reduce the value of χ . This makes it doubtful that the limit has the two-thirds value of 1033×10^{-6} . More precise measurements at still lower concentrations will be necessary to settle the question.

TABLE 3

Solution	Mole Ratio	Pull (Corrected)	K (Solution) $-K$ (Ammonia), $\times 10^6$	Moles per cc.	χ (Sodium), $\times 10^6$
-33°					
1	2.41×10^{-4}	0.154 mg.	0.00639	9.64×10^{-6}	663
2	2.32×10^{-4}	0.152 mg.	0.00630	9.29×10^{-6}	679
3	8.0×10^{-5}	0.102 mg.	0.00423	3.20×10^{-6}	1320
4	9.1×10^{-5}	0.075 mg.	0.00311	3.64×10^{-6}	855
-55°					
1	2.41×10^{-4}	0.094 mg.	0.00390	1.00×10^{-5}	390
2	2.32×10^{-4}	0.098 mg.	0.00406	9.63×10^{-6}	422
3	8.0×10^{-5}	0.083 mg.	0.00344	3.32×10^{-6}	1040
4	9.1×10^{-5}	0.062 mg.	0.00257	3.78×10^{-6}	680

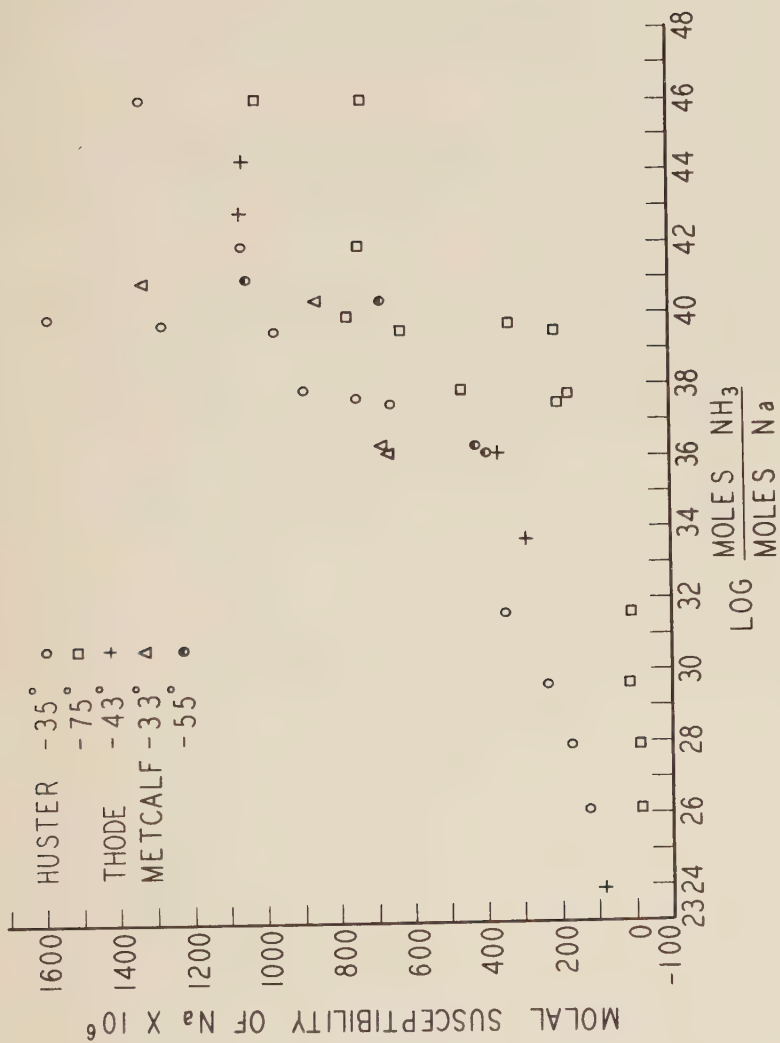


Fig. 3

SUMMARY

Preparations have been made for extending the measurements of the magnetic susceptibility of solutions of sodium in liquid ammonia to higher dilutions in order to obtain further information concerning the nature of the negative carriers of electricity in these solutions.

A method of using the balance, applicable to magnetic susceptibility determinations, has been devised which greatly increases the reproducibility of the rest point and, consequently, the accuracy attainable.

An apparatus has been constructed for determining magnetic susceptibilities by the Gouy method, whereby the forces can be measured to 0.001 mg. Extensive tests of this apparatus have disclosed its present limitations and suggested their causes.

The magnetic susceptibilities of four solutions of sodium in liquid ammonia have been determined. The results, which cannot be considered conclusive, suggest that the limiting value of the molal susceptibility at low concentrations is higher than was indicated by earlier measurements in this laboratory.

